C5.8.3 Expansion joints

C5.8.3.1 General

C5.8.3.1.1   Policy overview
Methods Memo No. 86: New Policy for Bridge Approach Slabs
23 October 2003

See C6.5.4.1.2.

C5.8.3.1.2   Design information
Iowa State University research on strip seal performance [BDM 5.8.3.1.5] has indicated that the AASHTO Procedure A cold climate temperature range [AASHTO-LRFD 3.12.2.1] generally is correct for steel but unconservative for concrete superstructures. The research also showed that the thermal coefficient for steel superstructures ($0.0000065/ \,^o$F) in the AASHTO Standard Specifications [10.2.2] generally is correct, the office shrinkage coefficient for concrete superstructures (0.0002 in/in) is reasonable but difficult to verify, and the thermal coefficient for concrete superstructures ($0.000006/ \,^o$F) in the AASHTO Standard Specifications [8.5.3] is conservative. Based on the research and long-term experience with expansion joints, the office policy is to use the temperature ranges and coefficients in Table 5.8.3.1.2 to determine movements for deck expansion joints.

C5.8.3.1.3   Definitions

C5.8.3.1.4   Abbreviations and notation

C5.8.3.1.5   References

C5.8.3.2 Strip seals

C5.8.3.2.1   Analysis and design
These two examples illustrate how to select and specify strip seals. Example 1 is for a steel bridge with characteristics that permit use of only one manufacturer's seal. Example 2 is for a concrete bridge with characteristics that permit use of alternate seals, as preferred by the office.

Example 1
Given: steel bridge, 420 feet long, 210-foot expansion length, 30-degree skew

Make preliminary selection.
For 30-degree skew, Table 5.8.3.2.1-1 lists maximum expansion length of 260 feet for Wabo SE-300 and 345 feet for Wabo SE-400. D.S. Brown A2R-400 is not acceptable. Try Wabo SE-300.

Check allowable movement capacity parallel with centerline of roadway for Wabo SE-300.
$(\Delta L)_{thermal} = \alpha \, L \, \Delta T = (0.0000065)(210)(12)(150) = 2.46$ inches
$(\Delta L)_{shrink} = k \, L = (0)(210)(12) = 0$ inches
$(\Delta L)_{total} = 2.46 + 0 = 2.46$ inches [< 3.5 inches from Table 5.8.3.2.1-2, OK]

Check long-term maximum joint opening. [Numerical subscripts refer to temperatures in degrees Fahrenheit. Shrinkage is zero and not shown.]
Try 1.5 inch at 90 °F joint setting for best installation options.
$Width_{-25} = Setting_{90} + (\Delta L)_{115} = 1.5 + (0.0000065)(210)(12)(115)(\cos 30) = 3.13$ inches [> 3 inches {minimum of seal size and $(3.5)(\cos 30) = 3.03$ inches, Table 5.8.3.2.1-2}, NG]

Try 1.5 inch at 80 °F joint setting.
Width$_{-25}$ = Setting$_{80}$ + $(\Delta L)_{105}$ = 1.5 + (0.0000065)(210)(12)(105)(cos 30) = 2.99 inches [< 3 inches {minimum of seal size and (3.5)(cos 30) = 3.03 inches, Table 5.8.3.2.1-2}, OK]

Check short-term minimum joint opening.
Width$_{125}$ = Setting$_{80}$ − $(\Delta L)_{45}$ = 1.5 − (0.0000065)(210)(12)(45)(cos 30) = 0.86 inches [> 0 inches, Table 5.8.3.2.1-2, OK]

Determine joint settings for plans.
Setting$_{50}$ = Setting$_{80}$ + $(\Delta L)_{30}$ = 1.5 + (0.0000065)(210)(12)(30)(cos 30) = 1.93 inches
$(\Delta L)_{40}$ = α L ΔT = (0.0000065)(210)(12)(40)(cos 30) = 0.57 inches
Setting$_{10}$ = Setting$_{50}$ + $(\Delta L)_{40}$ = 1.93 + 0.57 = 2.50 inches
Setting$_{90}$ = Setting$_{50}$ − $(\Delta L)_{40}$ = 1.93 − 0.57 = 1.36 inches

Determine maximum gland installation temperature.
Maximum installation temperature is 80 °F from joint setting trial above.

Specify only one strip seal: Wabo SE-300 with joint settings of 1 3/8 inches at 90 °F, 1 15/16 inches at 50 °F, and 2 1/2 inches at 10 °F. Specify that maximum gland installation temperature is 80 °F.

(It would be conservative in this example to specify Wabo SE-400.)

Example 2

Given: Concrete bridge, 600 feet long, 300-foot expansion length, 10-degree skew

Make preliminary selection.
For 10-degree skew, Table 5.8.3.2.1-1 lists maximum expansion length of 375 feet for Wabo SE-400 and 300 feet for D.S. Brown A2R-400. Try Wabo SE-400, and then try D.S. Brown A2R-400.

Check allowable movement capacity parallel with centerline of roadway for Wabo SE-400.
$(\Delta L)_{thermal}$ = α L ΔT = (0.000006)(300)(12)(100) = 2.16 inches
$(\Delta L)_{shrink}$ = k L = (0.0002)(300)(12) = 0.72 inches
$(\Delta L)_{total}$ = 2.16 + 0.72 = 2.88 inches [< 4.1 inches from Table 5.8.3.2.1-2, OK]

Check long-term maximum joint opening. [Numerical subscripts refer to temperatures in degrees Fahrenheit.]
Try 1.5 inch at 90 °F joint setting as best installation option.
Width$_0$ = Setting$_{90}$ + $(\Delta L)_{90}$ + $(\Delta L)_{shrink}$ = 1.5 + (0.000006)(300)(12)(90)(cos 10) + (0.72)(cos 10) = 4.12 inches [> 4 inches {minimum of seal size and (4.1)(cos 10) = 4.04 inches, Table 5.8.3.2.1-2}, NG]

Try 1.5 inch at 80 °F joint setting.
Width$_0$ = Setting$_{80}$ + $(\Delta L)_{80}$ + $(\Delta L)_{shrink}$ = 1.5 + (0.000006)(300)(12)(80)(cos 10) + (0.72)(cos 10) = 3.91 inches [< 4 inches {minimum of seal size and (4.1)(cos 10) = 4.04 inches, Table 5.8.3.2.1-2}, OK]

Check short-term minimum joint opening.
Width$_{100}$ = Setting$_{80}$ − $(\Delta L)_{20}$ = 1.5 − (0.000006)(300)(12)(20)(cos 10) = 1.07 inches [> 0 inches, Table 5.8.3.2.1-2, OK]

Determine joint settings for plans.
Setting$_{50}$ = Setting$_{80}$ + $(\Delta L)_{30}$ = 1.5 + (0.000006)(300)(12)(30)(cos 10) = 2.14 inches
$(\Delta L)_{40}$ = α L ΔT = (0.000006)(300)(12)(40)(cos 10) = 0.85 inches
Setting$_{10}$ = Setting$_{50}$ + $(\Delta L)_{40}$ = 2.14 + 0.85 = 2.99 inches

$Setting_{90} = Setting_{50} - (\Delta L)_{40} = 2.14 - 0.85 = 1.29$ inches

Determine maximum gland installation temperature.
Maximum installation temperature is 80 °F from joint setting trial above.

Try D.S. Brown A2R-400.

Allowable movement capacity check will be the same as for the Wabo SE-400 seal.

Check long-term maximum joint opening.
Because Table 5.8.3.2.1-1 shows seal type to meet expansion length with no excess, try 2.0 inch at 60 °F joint setting.
$Width_0 = Setting_{60} + (\Delta L)_{60} + (\Delta L)_{shrink} = 2.0 + (0.000006)(300)(12)(60)(\cos 10) + (0.72)(\cos 10) = 3.99$ inches [< 4 inches {minimum of seal size and $(4.1)(\cos 10) = 4.04$ inches, Table 5.8.3.2.1-2, OK]

Check short-term minimum joint opening.
$Width_{100} = Setting_{60} - (\Delta L)_{40} = 2.0 - (0.000006)(300)(12)(40)(\cos 10) = 1.15$ inches [> 0.5 inches, Table 5.8.3.2.1-2, OK]

Determine joint settings for plans.
$Setting_{50} = Setting_{60} + (\Delta L)_{10} = 2.0 + (0.000006)(300)(12)(10)(\cos 10) = 2.21$ inches
$(\Delta L)_{40} = \alpha\, L\, \Delta T = (0.000006)(300)(12)(40)(\cos 10) = 0.85$ inches
$Setting_{10} = Setting_{50} + (\Delta L)_{40} = 2.21 + 0.85 = 3.06$ inches
$Setting_{90} = Setting_{50} - (\Delta L)_{40} = 2.21 - 0.85 = 1.36$ inches

Determine maximum gland installation temperature.
Maximum installation temperature is 60 °F from joint setting trial above.

Specify two, alternate strip seals:
- Wabo SE-400 with joint settings (to nearest 1/16 inch): 1 5/16 inch at 90 °F, 2 1/8 at 50 °F, and 3 inches at 10 °F and maximum gland installation temperature of 80 °F and
- D.S. Brown A2R-400 with joint settings (to nearest 1/16 inch): 1 3/8 inch at 90 °F, 2 3/16 at 50 °F, and 3 1/16 inches at 10 °F and maximum gland installation temperature of 60 °F.

C5.8.3.2.2   Detailing

C5.8.3.3 Finger joints

C5.8.3.3.1   Analysis and design
Methods Memo No. 30: Finger Joints
5 February 2002 (corrections in bold, 17 April 2009)

Recently there has been the need to use finger joints on a number of projects (Design No. 2197-Polk/Warren, Des No. 1199-Woodbury, and Des. No. 500-Woodbury). Finger joints are required when thermal movements exceed those which can be accommodated by strip seals. Strip seals can accommodate movements up to about 5" (125 mm). Consult with your section leader before using finger joints to accommodate movements that exceed 10" (250 mm). Based on the 1998 **(and 2007 with 2008 Interim)** AASHTO LRFD Bridge Design Specifications and reports from NCHRP (NCHRP 141, 1989) and FHWA (FHWA Technical Advisory, 1980), the following recommendations for the design of finger joints have been adopted.

1. Limit deck surface openings to permit safe operation of motorcycles. When the maximum longitudinal opening in the direction of traffic exceeds 8" (200 mm), the transverse opening shall not exceed 2" (50 mm). For longitudinal openings less than 8" (200 mm), the transverse opening may be increased to 3" (75 mm). [AASHTO LRFD 14.5.3.2]
2. Where narrow bicycle tires are anticipated, use special floor plates in the shoulder area. [AASHTO LRFD 14.5.3.2]
3. The minimum joint opening (maximum design temperature) in the longitudinal direction is 0.5" (12 mm).
4. The maximum joint opening (minimum design temperature) in the longitudinal direction shall maintain at least a 1.5" (38 mm) tooth overlap. [AASHTO LRFD 14.5.3.2]
5. Align teeth with respect to the bearing device. Typically, this will be in the longitudinal direction of the bridge unless the structure is on a curved alignment.
6. Give special attention to details of the joint anchorage system. On structural steel supported bridges, the joints should be rigidly connected to the stringers or girders.
7. Tooth thickness shall not exceed 3" (75 mm). If necessary the designer may either use stiffeners to support the fingers or let the fingers bear on a support beam. For examples, see plan details of the Saylorville Reservoir Bridge and the Iowa Illinois Memorial Bridge on I-74 over the Mississippi River, respectively.
8. As outlined in BDM **5.8.3.3.1 Analysis and design (corrected from 5.7.1 "Joints")**, the teeth shall be designed as cantilevers. An impact factor of 1.75 shall be used per AASHTO LRFD 3.6.2.1. Let the weight of one wheel with impact equal, W = 1.75*16 kips = 28.0 kips (1.75*72.5 kN = 126.88 kN). Let N equal the number of teeth in the width of the wheel. Based on AASHTO LRFD 3.6.1.2.5 "Tire Contact Area" use 20" (510 mm) for the width of one wheel. The load per tooth, W/N shall be applied 3" (75 mm) from the end of the tooth, or WN/2 shall be applied 1.5" (38 mm) from the end of the tooth, whichever produces the largest stress. Only the teeth on one side of the joint shall be considered as resisting the load. [American Civil Engineering Practice, 1902 ed., Robert Abbett]
9. Finger plate armor should be pierced with ¾" (20 mm) diameter vertical vent holes spaced not more than 18" (450 mm) on center in order to expel entrapped air. Hand packing of concrete under the armor is required. [AASHTO LRFD 14.5.3.5]
10. The top of the expansion device is to be parallel to grade and the end of each tooth is to be beveled a ¼" in 3" (6 mm in 75 mm). Maintain at least an **¼"** (**6** mm) gap between adjacent fingers.
11. Since finger joints are considered open joints, elastomeric drainage troughs are required to prevent deicing chemicals and debris from spilling onto the ends of the beams, bearings, and substructure elements below.

When considering the use of the elastomeric drainage troughs, three aspects are of primary concern: sheet type, elastomer, and trough details.

1. Sheet type
    a. Sheet types should be low durometer (50 to 60) and synthetic fabric reinforced.
    b. Thickness of the side curtains and the reinforced neoprene trough should be 1/4" (6 mm).

2. Elastomer
   Place the following standard note on the plans **[See OM IM 494.]**: "The elastomer compound for trough and curtains shall be in accordance with table B of article 4195.02 of the standard specifications, except the tensile strength shall be 1500psi (10.3 MPa) minimum or it shall be (EPDM) Ethylene Propylene Diene Monomer (ASTM D 2000, Line call-outs 3BA, 515, A14, B13, F17, C12, **and** K21 **(Omit, Z1, Z2)**))."

3. Joint Details (See Figure)
    a. To limit the possibility of debris accumulation, a minimum slope of 8% is required for the drainage trough.

b. Drainage troughs should be continuous full width of the bridge including curb and parapet area when the joint is over a pier or at an abutment and elsewhere where a closed drainage system is required. Keep the drainage trough continuous the full width of the bridge, where possible. If not, check with the section leader.

c. If splicing of the elastomeric sheet side curtains is necessary, a minimum splice length (overlap) of 2' (610 mm) is recommended, overlap of the upstream sheet shall be on the inside relative to the downstream sheet.

d. The finished joint should be recessed **1/4" (6 mm)** to avoid damage by traffic or snow removal equipment.

e. All hardware, including bolts, studs, washers and concrete anchors, used to attach the trough shall be stainless steel.

f. The troughs should be attached in a secure manner with a minimum of 5/8" (15.9 mm) diameter bolts at 18" (450 mm) centers.
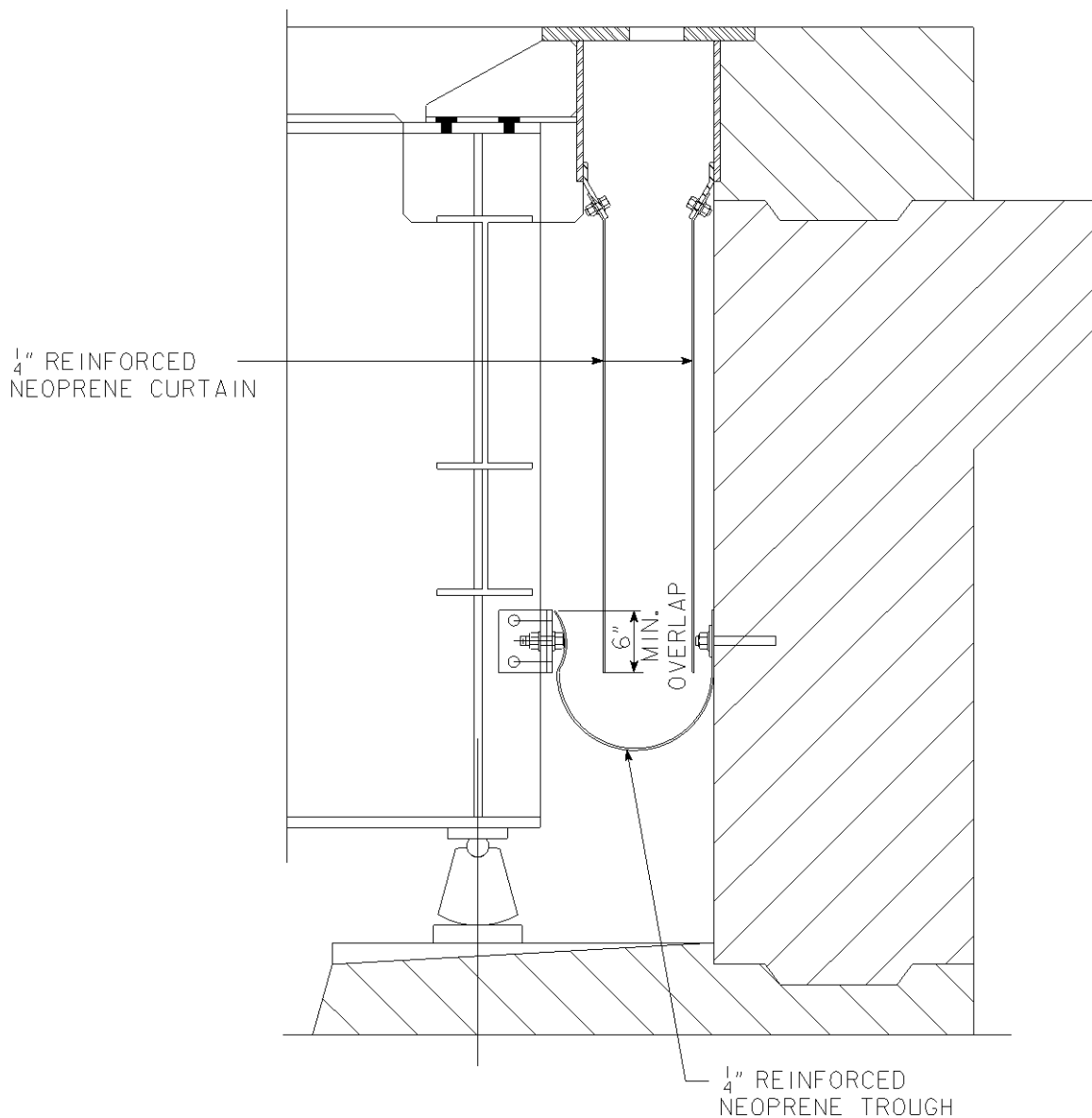
C5.8.3.3.2   Detailing

C5.8.3.4 Tire buffings joints

C5.8.3.4.1   Analysis and design
Methods Memo No. 86: New Policy for Bridge Approach Slabs
23 October 2003

See C6.5.4.1.2.

C5.8.3.4.2   Detailing

C5.8.3.5 Other joints